Energy Supply Technologies: Wind Power

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IEA EGRD: Monitoring Progress towards a Cleaner Energy Economy

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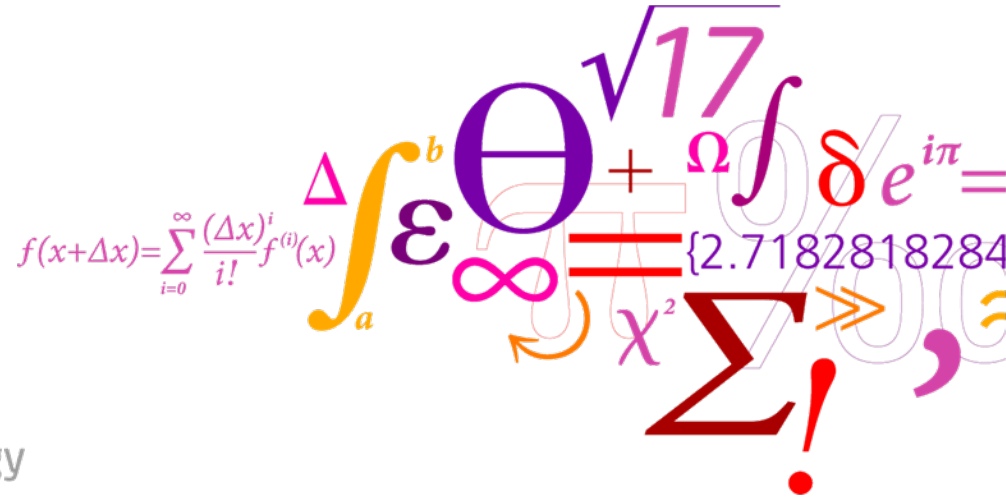
November 16th, 2011



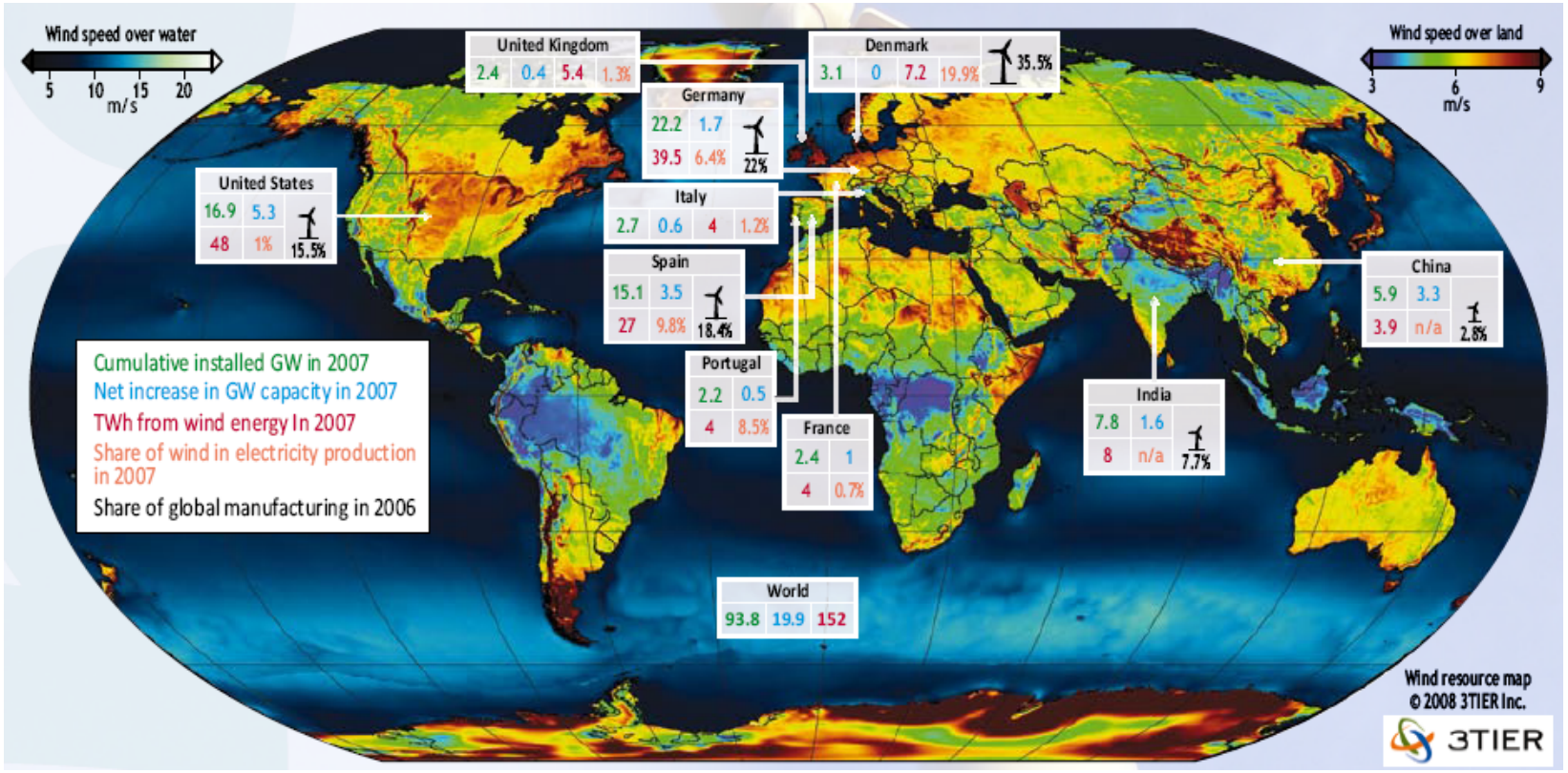
Risø DTU

National Laboratory for Sustainable Energy

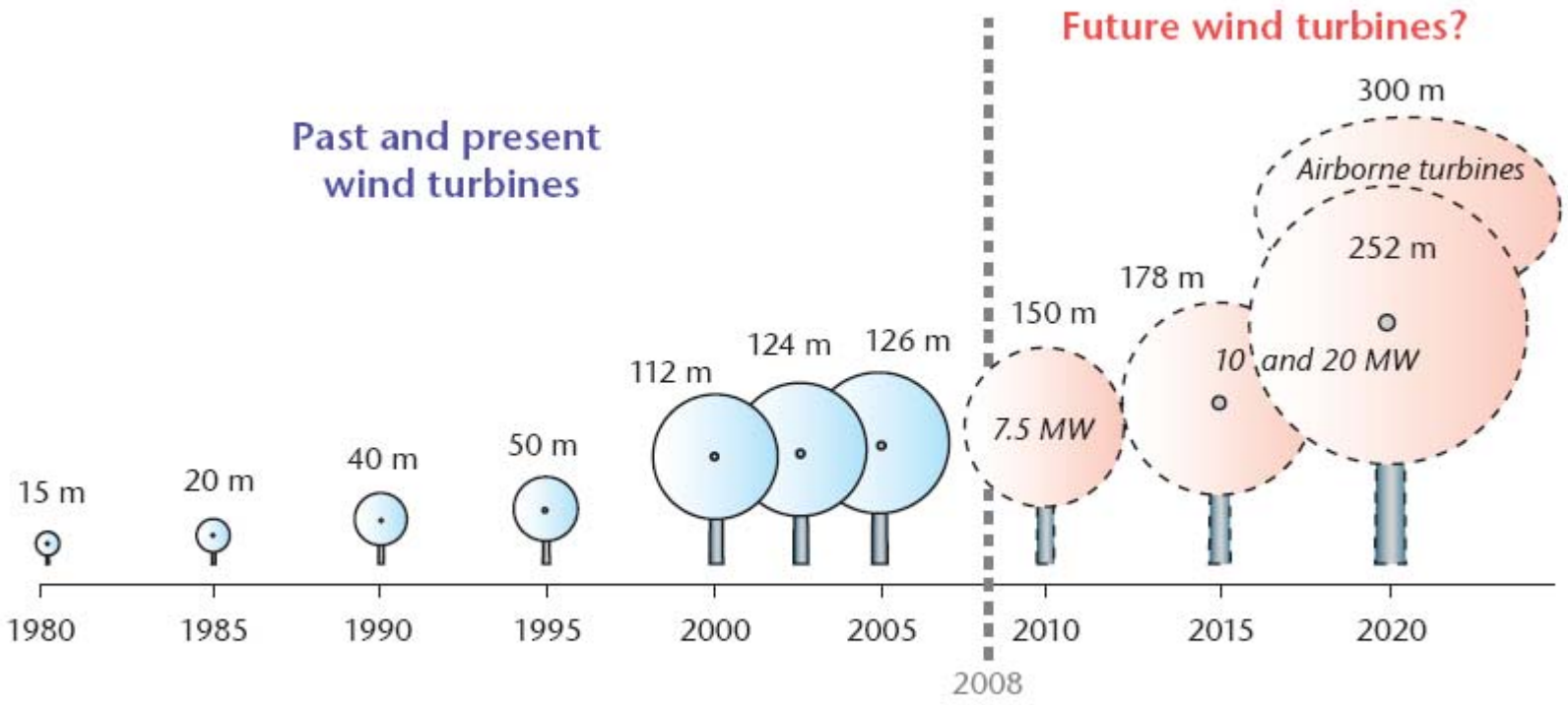
Outline

1. **Wind power: world market and cost developments**
2. Market policy measures
3. RD&D measures
4. Indicators
5. Conclusions and recommendations

Overview: wind resources



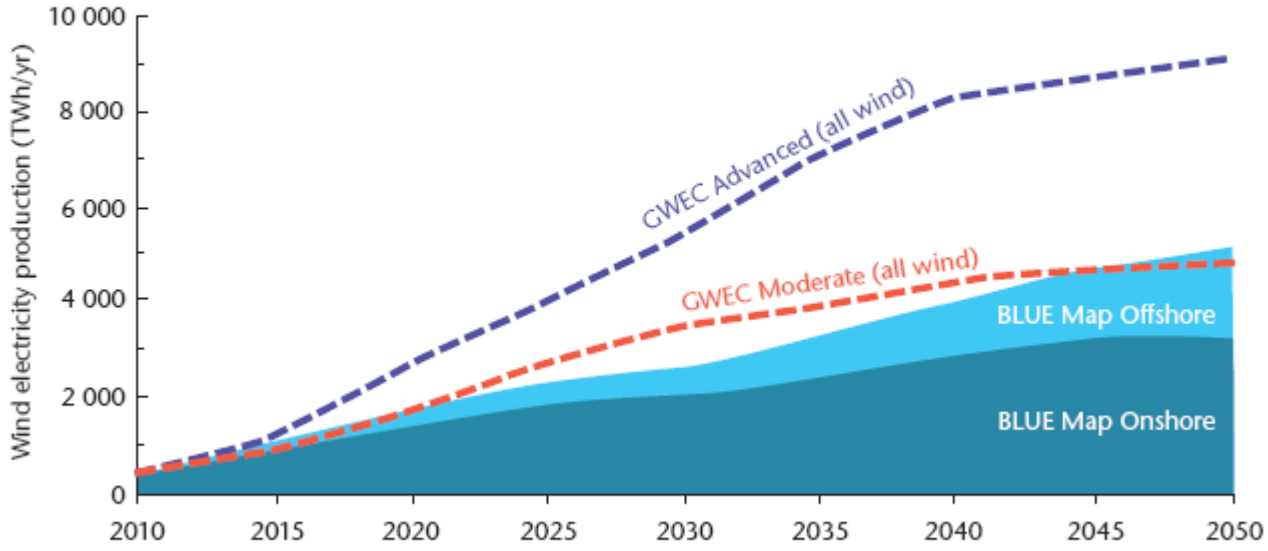
Up-Scaling



Source: IEA Technology Roadmap Wind Energy, adapted from EWEA (2009)

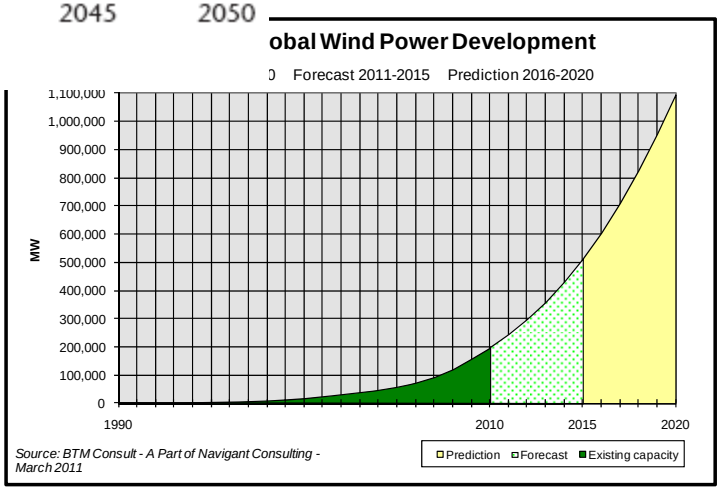
Diverging predictions: IEA vs. GWEC

Figure 5: Wind electricity production in ETP 2008 BLUE Map scenario and industry analysis



Source: IEA (2008a), Global Wind Energy Council (GWEC) (2008).

2010:
159 GW – Blue Map
197 GW – GWEC
199 GW – BTM



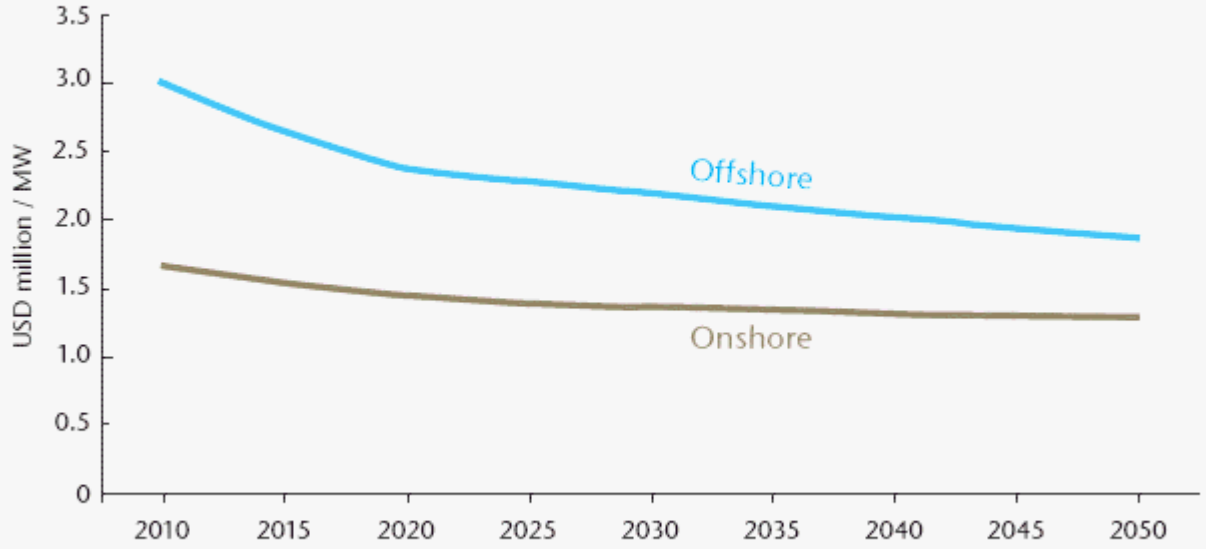
Industry structure: Today's manufacturers

	Accu. MW 2009	Supplied MW 2010	Share 2010 %	Accu. MW 2010	Share accu. %
VESTAS (DK)	39,705	5,842	14.8%	45,547	22.8%
SINOVEL (PRC)	5,658	4,386	11.1%	10,044	5.0%
GE WIND (US)	23,075	3,796	9.6%	26,871	13.5%
GOLDWIND (PRC)	5,315	3,740	9.5%	9,055	4.5%
ENERCON (GE)	19,798	2,846	7.2%	22,644	11.3%
SUZLON GROUP (IND)	14,565	2,736	6.9%	17,301	8.7%
DONGFANG (PRC)	3,765	2,624	6.7%	6,389	3.2%
GAMESA (ES)	19,225	2,587	6.6%	21,812	10.9%
SIEMENS (DK)	11,213	2,325	5.9%	13,538	6.8%
UNITED POWER (PRC)	792	1,643	4.2%	2,435	1.2%
Others	22,045	8,247	20.9%	30,292	15.2%
Total	**165,156**	**40,771**	**103%**	**205,927**	**103%**

Source: BTM Consult - A Part of Navigant Consulting - March 2011

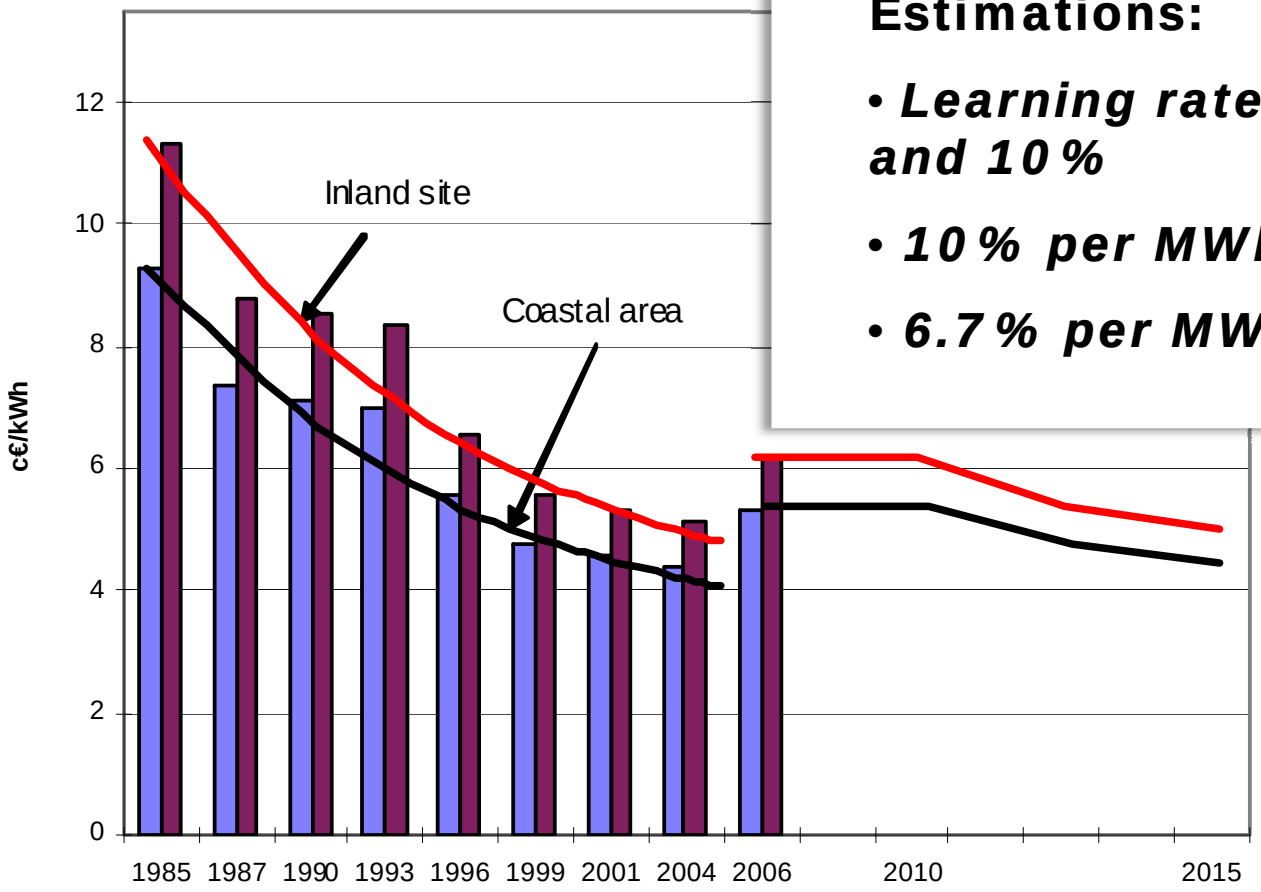
Blue Map Assumptions on Cost Development

Figure 8: ETP BLUE Map scenario projections for development of onshore and offshore wind investment costs (USD/MW)



Source: IEA (2008a).

Experience Curve for Wind Power Unit Cost

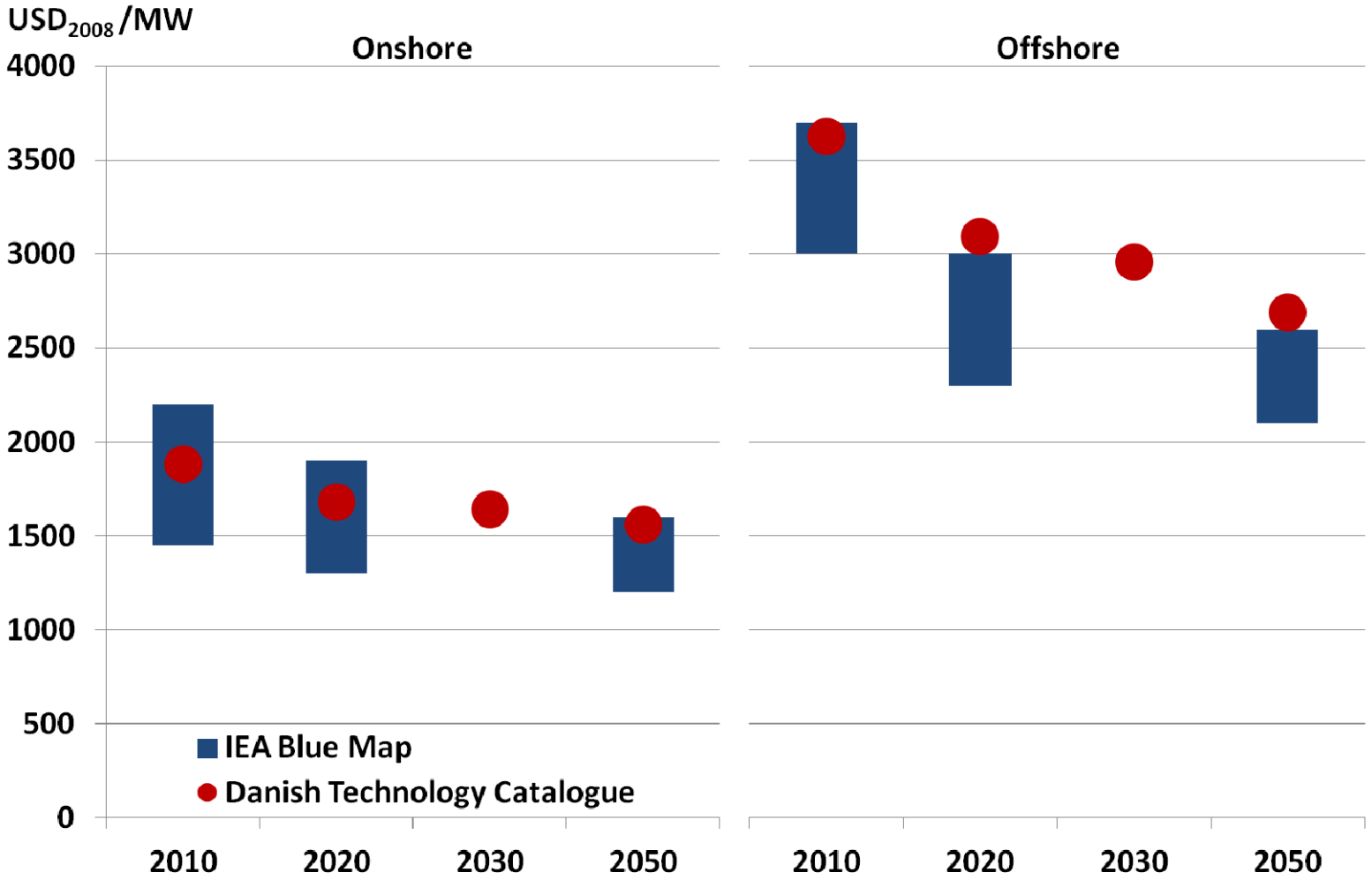


Estimations:

- ***Learning rate between 6.7% and 10%***
- ***10% per MWh***
- ***6.7% per MW***

Source: J. Lemming, P.E. Morthorst, Risø DTU

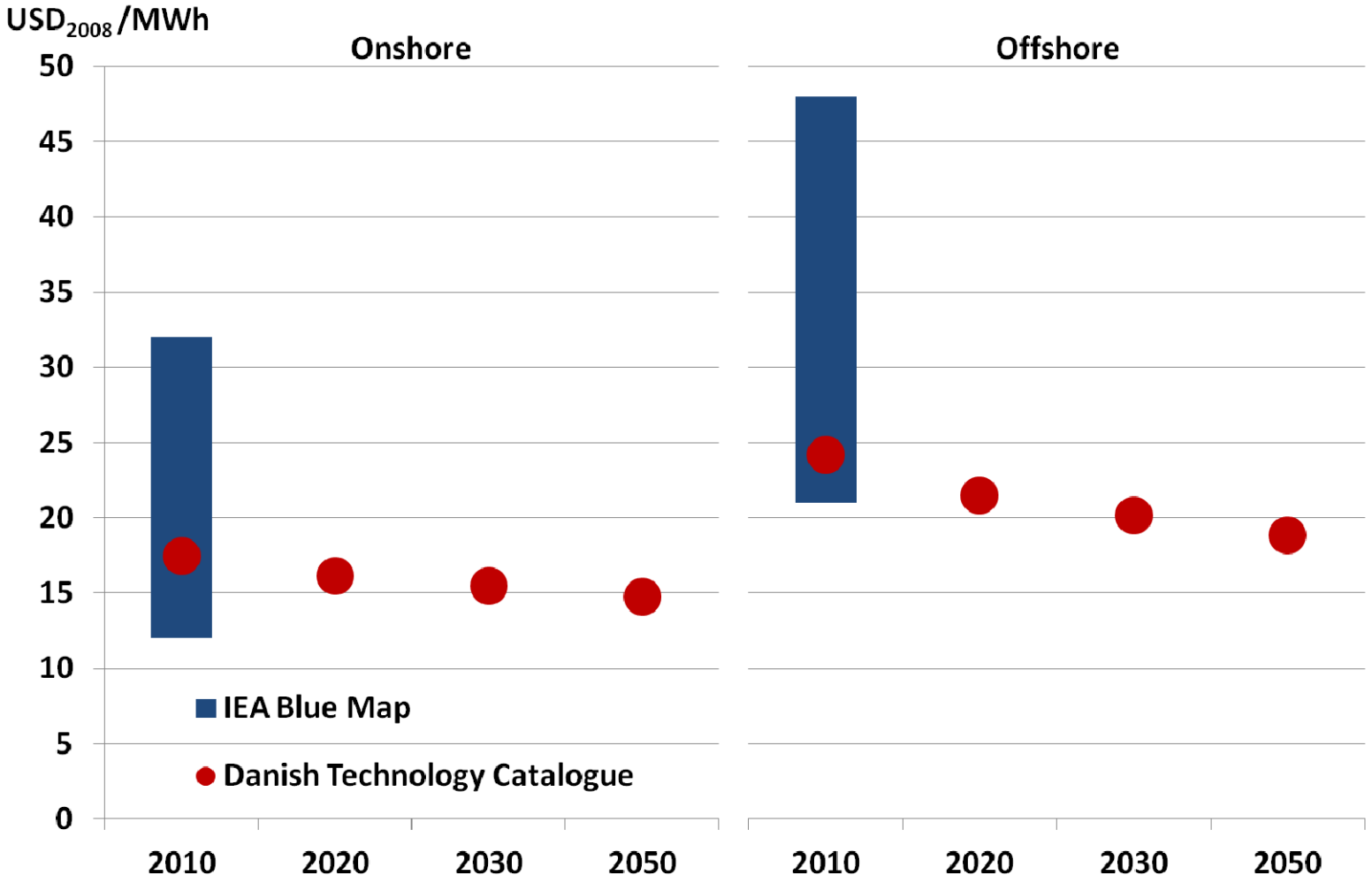
Wind: investment cost development



Exchange rate: 1€ = 1.344$

Danish Technology Catalogue based on “Vindmøllers økonomi" (Economy of wind turbines), final report prepared by the project 'Economy of wind turbines 2007-2009', with major Danish stakeholders as participants. P. Nielsen, EMD International, et al, January 2010.

Wind: O&M cost development



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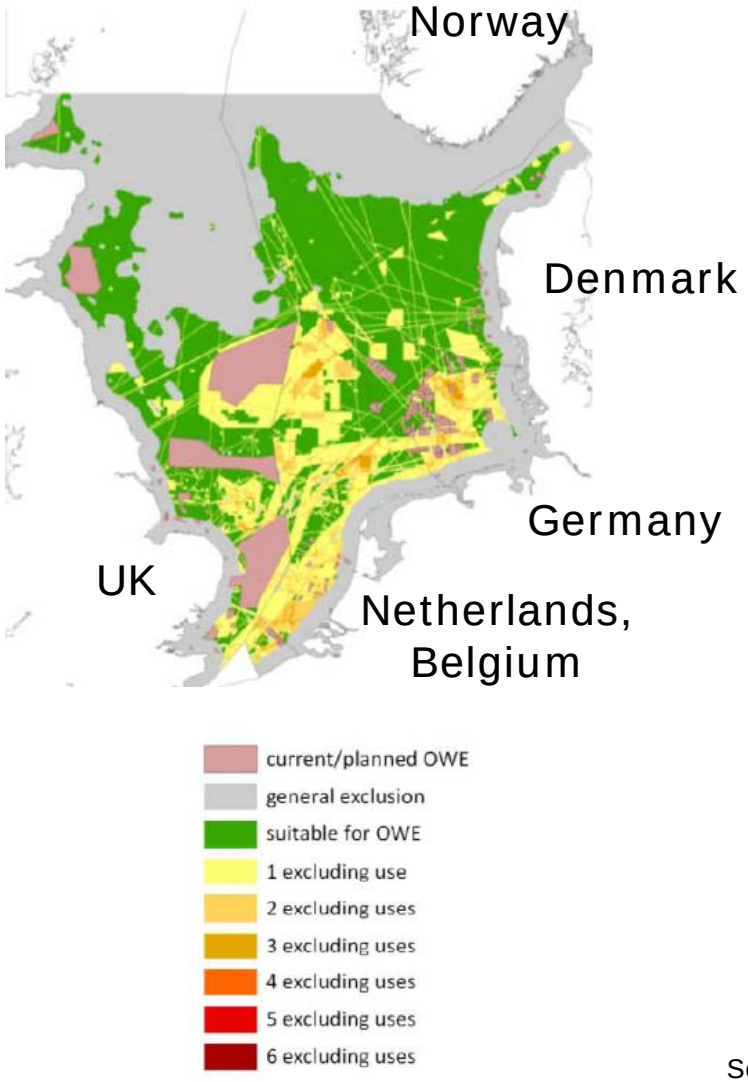
Policies: Grid integration

- Grid Codes
  - individual regimes for single RES technologies, depending on their market penetration
- Priority Access
- Connection charges
  - shallow / shallowish / deep
- In densely populated areas: include population!

Integrated system planning



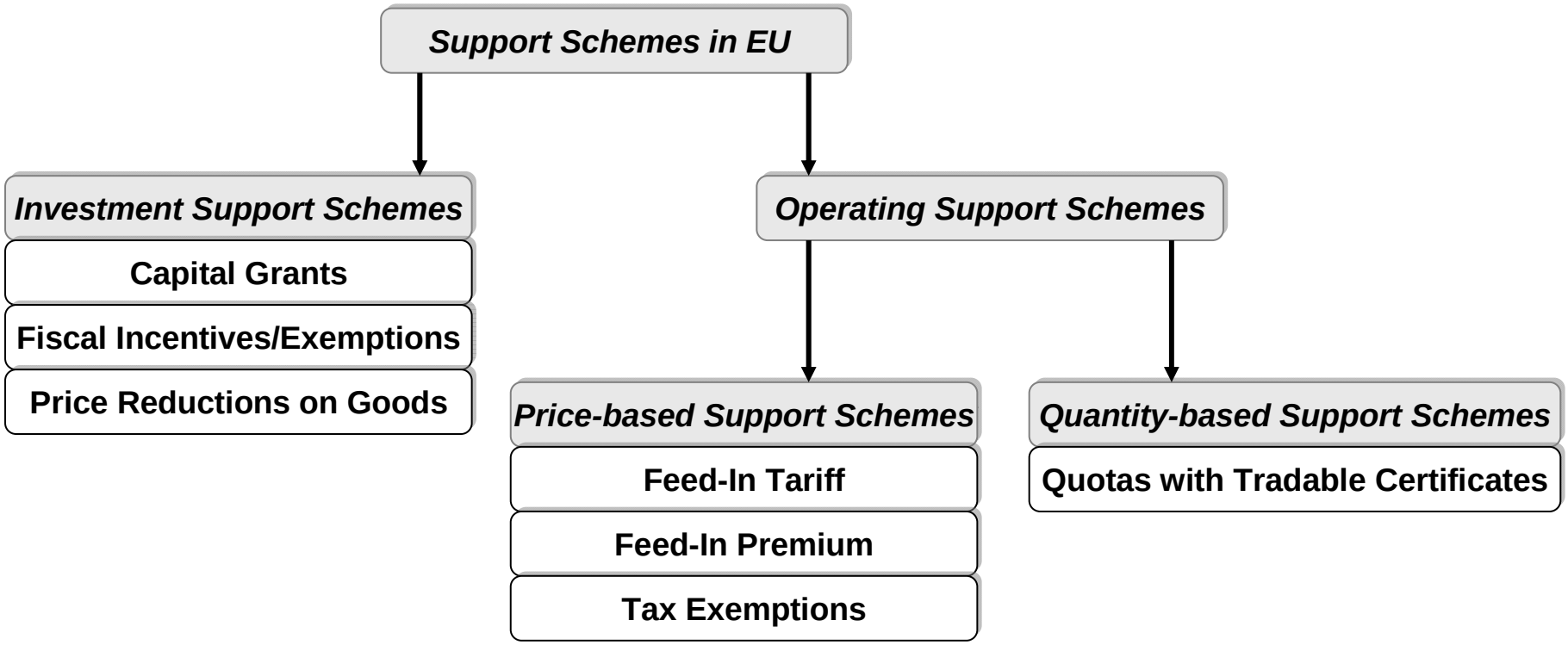
Planning procedures:

•Offshore: government in charge of the initial development phase, nominates specific areas

•Onshore: open competition (except for very large projects)

Source: WINDSPEED project (Veum et al., 2011), Grand Design

Overview Support Schemes



Source: IMPROGRES Report (Cali et al., 2009)

Policy effectiveness indicators

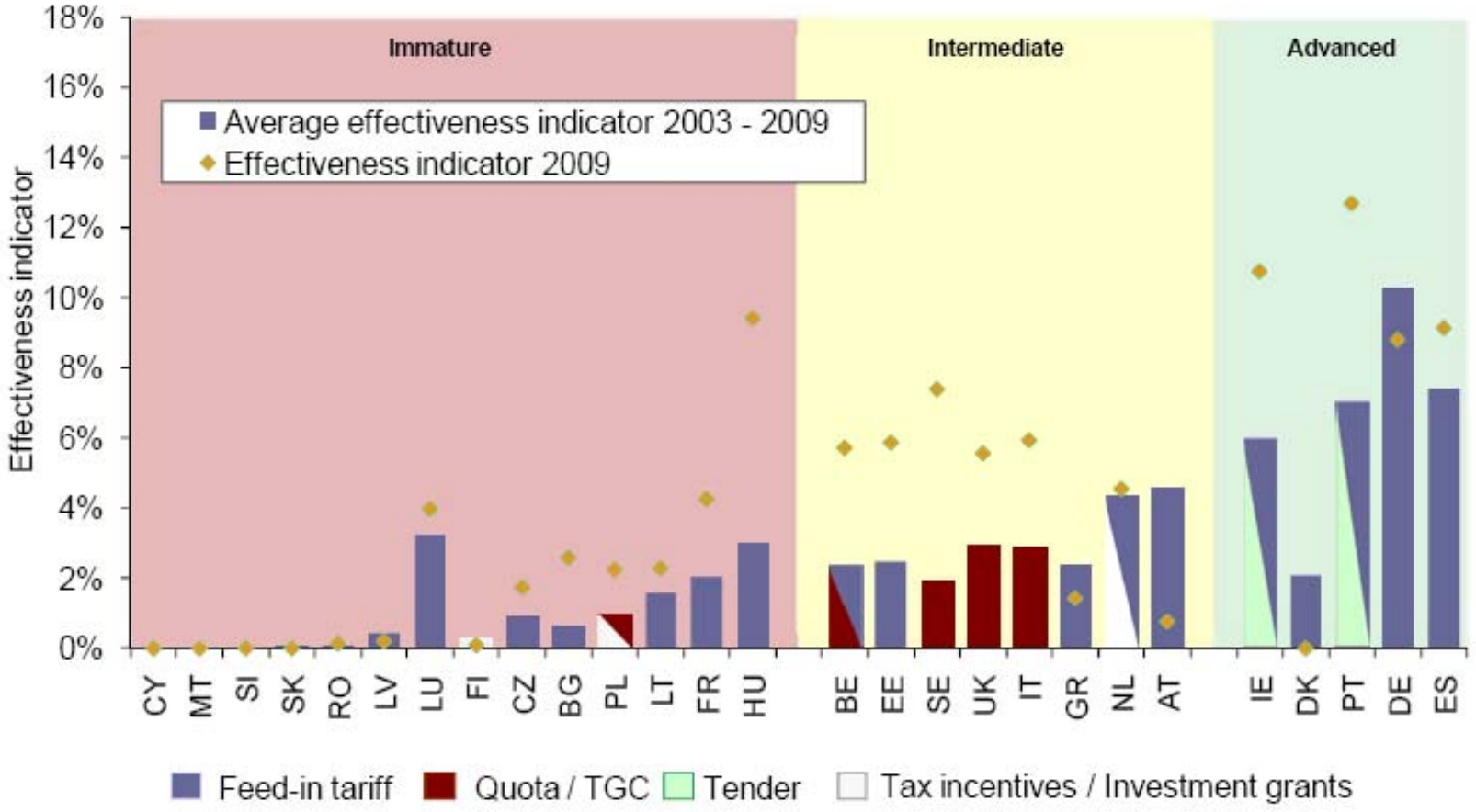


Figure 4-9: Policy Effectiveness Indicator for wind on-shore power plants in the period 2003 - 2009. Countries are sorted according to deployment status indicator

Source: RE-Shaping project (Deliverable 8, Ragwitz et al., 2011)

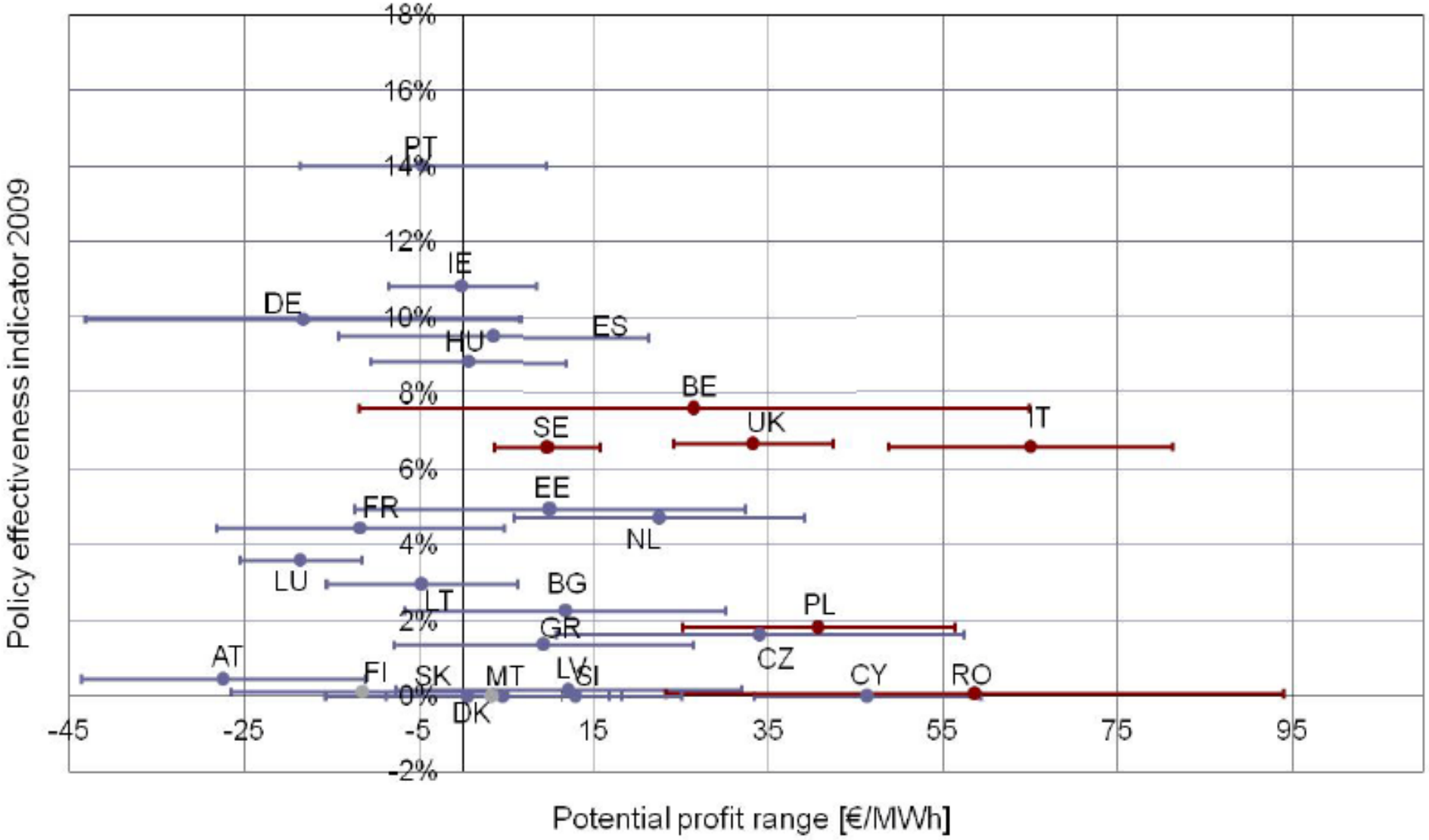


Figure 4-6: Potential profit ranges (Average to maximum remuneration and minimum to average generation costs) available for investors in 2009 and Policy Effectiveness Indicator for wind onshore in 2009

Source: RE-Shaping project (Deliverable 17, Steinhilber et al., 2011)

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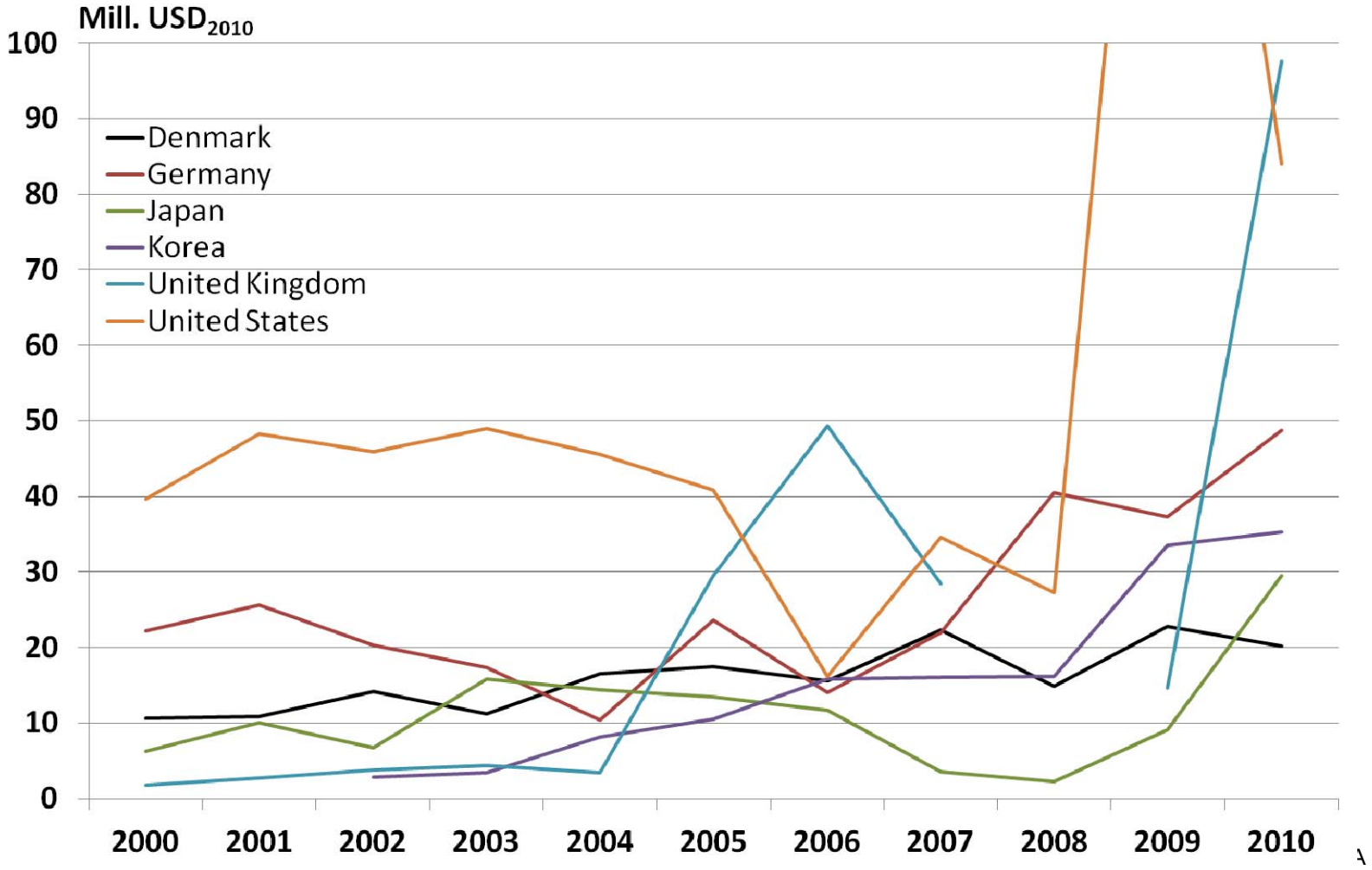
2000-2010: Total RD&D for wind energy

(selected countries: Top 6 in 2010)

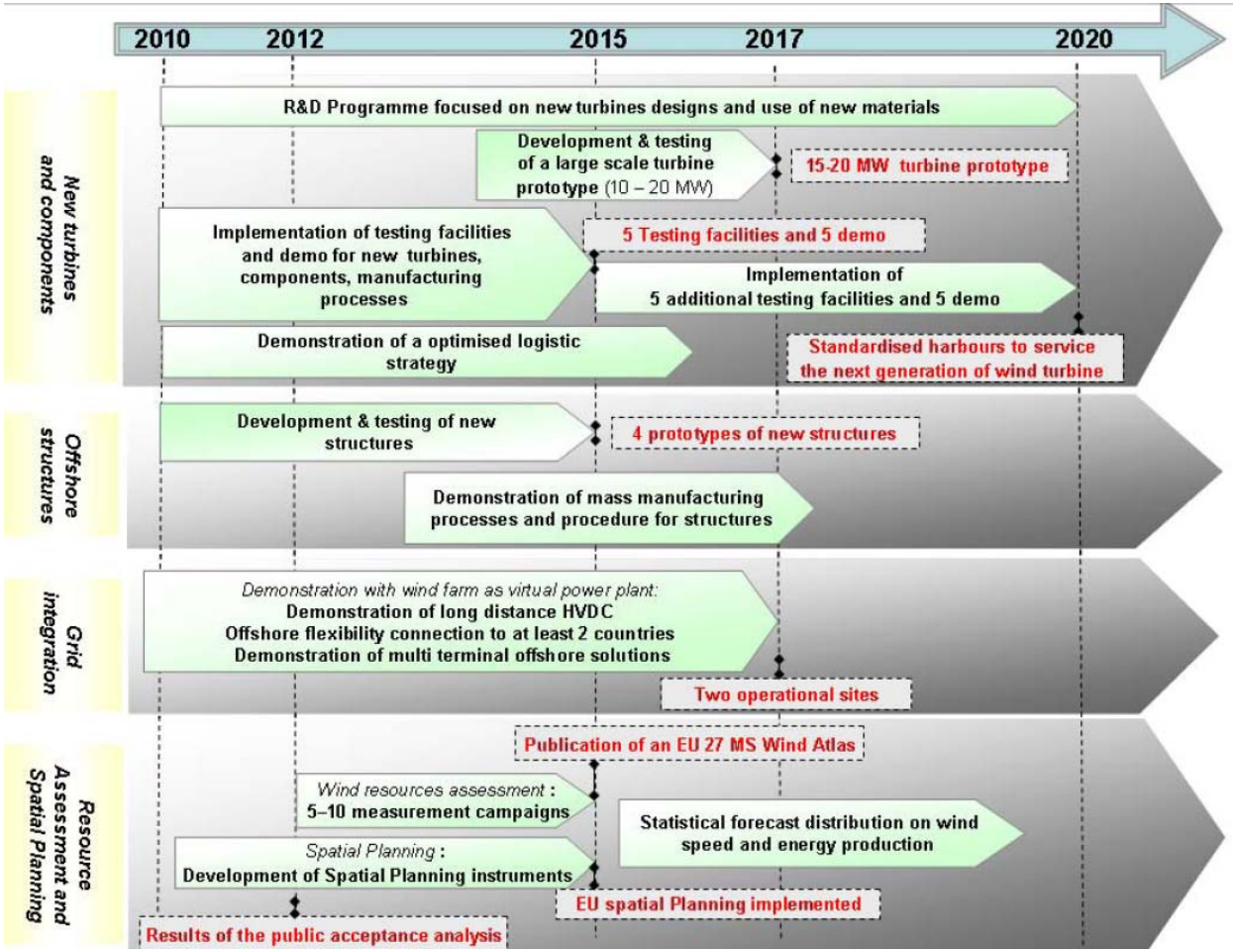


Strengthening RD&D in Denmark

- **Public-private Megavind, 2007**

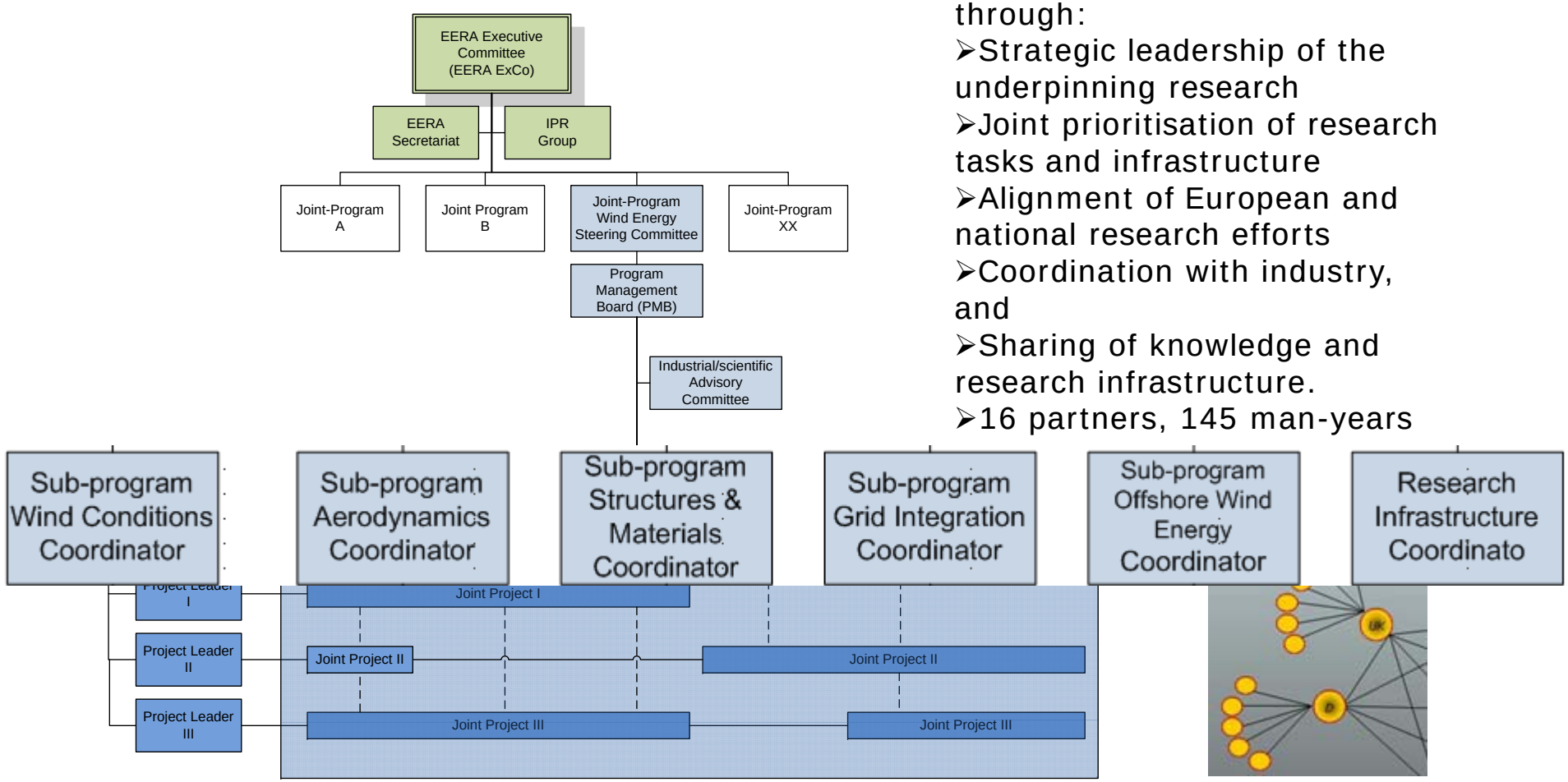
- Danish Research Consortium for Wind Energy
  - Established 2002 between Risø, AAU, DHI and DTU
  - New strong DTU Wind Energy department (Jan 2012)
  - New strategy and new partners in progress

Wind in the EU SET-plan, 2009



- 20% share of wind energy in final energy EU electricity consumption by 2020 (today 5%)
- 6B€
- Two pillars:
  - TPWind
  - EERA Joint Programme on Wind Energy

European Energy Research Alliance: Joint Program on Wind Energy



Added value to SET-Plan through:

- Strategic leadership of the underpinning research
- Joint prioritisation of research tasks and infrastructure
- Alignment of European and national research efforts
- Coordination with industry, and
- Sharing of knowledge and research infrastructure.
- 16 partners, 145 man-years

IEA Implementing Agreement on Wind

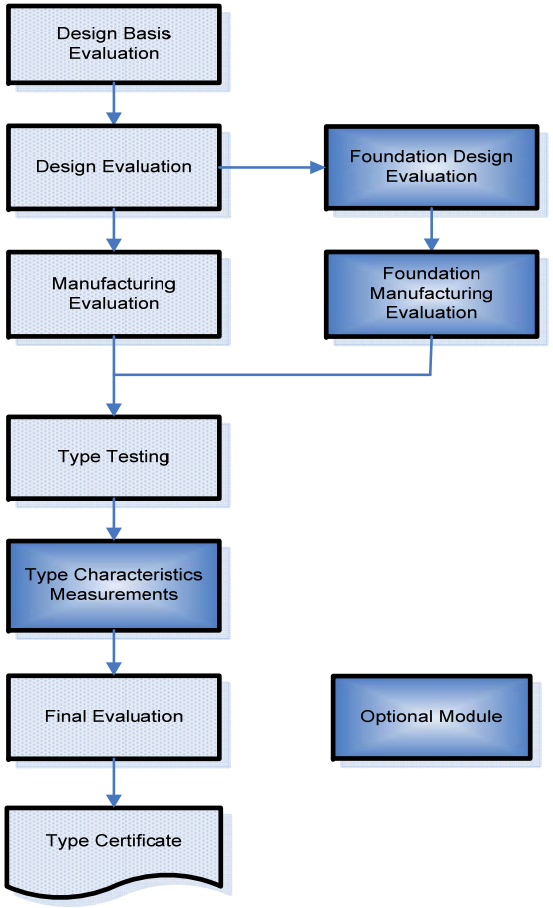
- 1977
- 2010: 21 participants, 2 sponsor participants (CWEA, EWEA)
- 9 active tasks

Task	Active Cooperative Research Task
Task 11	Base Technology Information Exchange
Task 19	Wind Energy in Cold Climates
Task 25	Power Systems with Large Amounts of Wind Power
Task 26	Cost of Wind Energy
Task 27	Consumer Labeling of Small Wind Turbines
Task 28	Social Acceptance of Wind Energy Projects
Task 29	Mexnex(T): Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models
Task 30	Offshore Code Comparison Collaborative Continuation
Task 31	WAKEBENCH: Benchmarking of Wind Farm Flow Models

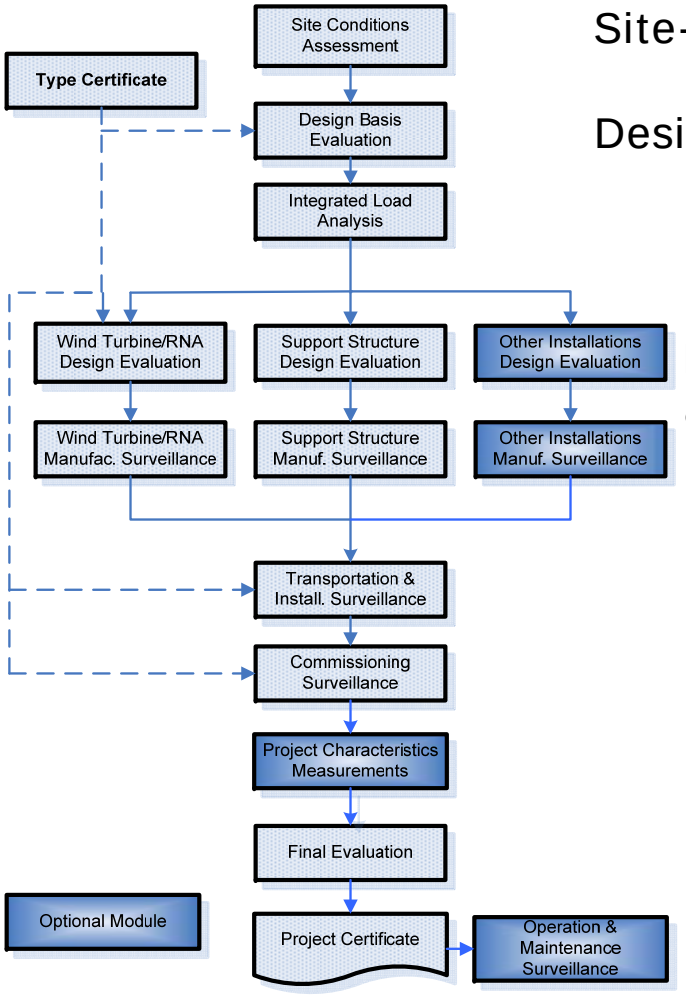
IEC TC88: IEC 61400 standards

- **IEC 61400-1 Design requirements**
- IEC 61400-2 Small wind turbines
- **IEC 61400-3 Design requirements for offshore wind turbines**
- IEC 61400-4 Gears for wind turbines
- IEC 61400-(5) Wind Turbine Rotor Blades
- IEC 61400-11, Acoustic noise measurement techniques
- IEC 61400-12-1 Power performance measurements
- IEC 61400-13 Measurement of mechanical loads
- IEC 61400-14 TS Declaration of sound power level and tonality
- IEC 61400-21 Measurement of power quality characteristics
- ***IEC 61400-22 Conformity Testing and Certification of wind turbines***
- IEC 61400-23 TR Full scale structural blade testing
- IEC 61400-24 TR Lightning protection
- IEC 61400-25-(1-6) Communication
- IEC 61400-26 TS Availability
- IEC 61400-27 Electrical simulation models for wind power generation
- IEC 60076-16: Transformers for wind turbines applications

Type Certification
(IEC 61400-22)



Project Certification
(IEC 61400-22)



Site-specific conditions

Design conditions

Load and design analysis

Surveillance

Certificate

Wind Power

Sample Metrics for Measuring Progress toward a Global Clean Energy Economy

Resources

- **Public RD&D investment in wind power technologies ($/yr) [1,3]**
- **Private RD&D investment in wind power technologies ($/yr) [1,3]**

Technology Readiness

- **Unsubsidized LCOE ($/kWh) and capital cost ($/kW) for new a) onshore and b) offshore installations [3]**
- Reduction in weight of a) rotor and b) drive-train (%) [5]
- Expected lifetime of new wind turbines (yrs) [1]
- Annual improvement in capacity factor (%) [2]

Market Readiness

- **Total value of subsidies issued for wind power ($/yr) [2]**
- **Percent of G20 countries with a) streamlined permitting procedures and b) grid integration policies for wind power deployment (%) [2]**
- Share of wind power generation meeting a quota obligation system (%) [3]
- Manufacturing capacity and production of a) large and b) small (<1 MW) turbines (MW/yr) [6]

Market Transformation

- **Installed capacity of a) onshore and b) offshore (GW) [3]**
- **Generation of a) onshore and b) offshore (TWh/yr) [4]**
- Learning rate: cost reduction for each doubling of cumulative installed capacity (%) [1]
- Wind share of electricity mix in G20 markets (%) [1]
- Average annual growth rate in wind power generation (%) [3]
- Market capitalization of wind companies ($)

Impacts

- GHG emissions avoided from use of wind energy (MtCO2e/yr) [6]
- Number of employees in wind energy workforce (#) [1,6]

Wind Power

Sample Metrics for Measuring Progress toward a Global Clean Energy Economy

Resources

- **Public RD&D investment in wind power technologies ($/yr) [1,3]**
- **Private RD&D investment in wind power technologies ($/yr) [1,3]**

Technology Readiness

- **Unsubsidized LCOE ($/kWh) and capital cost ($/kW) for new a) onshore and b) offshore installations [3]**
- Annual improvement in capacity factor (%) [2]
- Energetic amortization time (yrs)

Market Readiness

- **Total value of support issued for wind power ($/yr) [2]**
- Manufacturing capacity and production of a) large and b) small (<1 MW) turbines (MW/yr) [6]
- **Time duration from application till grid connection**

Market Transformation

- **Installed capacity of a) onshore and b) offshore (GW) [3]**
- **Generation of a) onshore and b) offshore (TWh/yr) [4]**
- Learning rate: cost reduction for each doubling of cumulative installed capacity (%) [1]
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- Average annual growth rate in wind power generation (%) [3]
- Market capitalization of wind manufacturers ($)

Impacts

- GHG emissions avoided from use of wind energy (MtCO2e/yr) [6]
- Number of employees in wind energy workforce (#) [1,6]

Wind energy: Other than electrical contributions

- Mechanical: on land (traditional pumping)
- Shipping

- Airborne technologies

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Conclusions and recommendations

- Wind energy is roughly on track, but are projections ambitious enough?

- Coherent energy RD&D strategies and robust public and private funding
- Basic: e.g. materials research (metals, concrete, composite materials), aerodynamics, wind potential analysis, system integration
- Public acceptance – support it by different measures, accompanied by research

- Implement international standardization and certification schemes

- Reliable conditions for investment decisions by policy measures (targets, support schemes)

- Facilitate the interplay of different options, e.g. by smart grids

- Remove non-economic barriers, trade barriers

Thank you for your attention!

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